Rev. Mexicana Astron. Astrof., 14, 87-89 (1987)

THE EFFECT OF RELATIVISTIC ELECTRONS ON THE NARROW EMISSION LINES OF AGN

S.M. Viegas-Aldrovandi and R.B. Gruenwald

Instituto Astronomico e Geofisico
Sao Paulo, Brazil

RESUMEN. Se presentan modelos de las regiones de líneas de emisión angostas en los núcleos activos de galaxias. Los modelos están construídos considerando que las nubes de emisión tienen diferentes densidades y que la intensidad de la línea está calculada de acuerdo a la función de distribución de las densidades de la nube. Una comparación entre los cocientes de líneas observadas y calculadas nos muestra que la presencia de electrones relativistas es importante y que puede mejorar los cocientes teóricos calculados por los modelos de ionización.

ABSTRACT. Models for the narrow emission lines regions of active galactic nuclei are presented. Models are constructed considering that the emitting clouds have different densities and the line intensities are calculated assuming a distribution function of the cloud densities. A comparison between the observed and calculated line ratios shows that the presence of relativistic electrons is important and can improve the theoretical ratios calculated by photoionization models.

Key words: GALAXIES-ACTIVE

I. INTRODUCTION

Relativistic electrons are present in galactic nuclei showing radio emission. After losing part of their energy by synchroton emission, these electrons may affect the physical conditions of the photoionized gas and the emission line intensities. Some systematic differences between the emission line spectra of radio galaxies and Seyfert galaxies have been pointed out by Cohen and Osterbrock (1981) and Grandi and Osterbrock (1978). The presence or not of high energy particles in these nuclei may contribute to the differences.

An estimate of the effect of relativistic electron on the emission lines has been obtained by Cesar et al. (1985) considering an optically thin photoionized cloud. Recently, Gruenwald and Viegas-Aldrovandi (1986) presented a grid of models taking into account the coupled effect of photoionization and relativistic electrons on the physical conditions of an optically thick cloud.

Since observations indicate that the narrow emission line region is composed by several emitting filaments with different densities, the observed emission lines result from the integrated emission of all clouds. So that, in this paper we present integrated models for the NLR of active nuclei considering a distribution of cloud densities and taking into account the effect of photoionization and relativistic electrons. The theoretical line intensity ratios are compared to the observed ratios.

II. INTEGRATED MODELS

Some integrated models for Liners have been presented by Binette (1985). In fact, these models represent a continuum in the value of the ionization parameter, U. However, the grid of single models on which the integrated models are based have been calculated assuming a constant hydrogen density equal to 400 cm^{-3}. Since most of the forbidden lines are sensitive to densities higher than 10^3 cm^{-3}, the presence of clouds with different densities can highly affect the results obtained by an integrated model. So that, our calculations have been performed considering this fact.

For each value of the ionization parameter, U, the emission line fluxes are obtained considering a weight function which represents the density distribution of the clouds. The single models have been given by Gruenwald and Viegas-Aldrovandi (1986) for densities $n_H = 10^2, 10^3, 10^4, 10^5$ and $10^6 cm^{-3}$. Line fluxes for intermediate densities have been obtained by interpolation. We assumed a power-law distribution ($\propto n_H^{-b}$) characterized by a power index $0. \leq b \leq 3$. Larger values of b do not change the results since for b = 3 most of the emission comes from the low density clouds. On the other hand, when compared to observations the results shown that there are a few number of active nuclei characterized by small value of b, which corresponds to a greater number of high density clouds relative to the number of low density clouds, so that, b = 0. is a good limit.

III. RESULTS

The fluxes of the more important emission lines have been calculated on basis on the integrated models described above. We consider single models given by Gruenwald and Viegas-Aldrovandi (1986) for $U = 10^{-2}, 10^{-3}$ and 10^{-4}cm/s, $10^2 \leq n_H \leq 10^6 cm^{-3}$ and excitation parameter characterizing the flux of relativistic electrons $\phi|n_H = 0$ and 10^5cm/s. The ionizing radiation spectrum is composed by ultraviolet and x-ray power law with $\alpha_{uv} = 2.5$ and $\alpha_x = 1.7$, respectively.

From the comparison between the theoretical and observed line ratios the importance of the relativistic electrons can be verified and the information on the density distribution of the emitting clouds can be obtained.

Following Stasinska (1984) several diagnostic diagrams have been plotted. The observational data have been taken from: Cohen (1983), Cohen and Osterbrock (1981), Costero and Osterbrock (1977), De Robertis and Osterbrock (1986) Grandi and Phillips (1979), Grandi and Osterbrock (1978), Koski (1978), Osterbrock et al. (1976), Phillips and Osterbrock (1975), Shuder (1980), Shuder and Osterbrock (1981).

An example of such diagnostic diagrams is shown in Fig. 1, where the ratios [OIII] 5007 + 4959/Hβ and [OIII] 5007 + 4959/[OII] 3727 are plotted. Dotted and solid lines correspond to integrated models considering $\phi|n_H = 0$ and 10^5cm/s, respectively. The curves are labelled A, B and C corresponding to $U = 10^{-2}$, 10^{-3} and 10^{-4}, respectively, and are parametrized by the values of the index of the power law distribution, b. The arrows indicate the direction of the increasing b and the ticks correspond to b = 0.5 and 1. Dashed and dotted-dashed curves correspond to models with b = 0. or 3. and $10^{-4} \leq U \leq 10^{-2}$cm/s. The observed objects are grouped following the radio emission. From this Figure, the presence of relativistic electrons enlarges the area of theoretical ratios allowing a better fit to observations. Most of the galactic nuclei are concentrated in the region characterized by $10^{-3} \leq U \leq 10^{-2}$ and $1. < b \leq 3.$.

As pointed out previously (Gruenwald, Viegas-Aldrovandi, 1986) the main effect of the relativistic electrons is the gas heating and an enlargement of the transition zone where low excitation lines are produced. Due to the temperature effect, some of the line ratios are

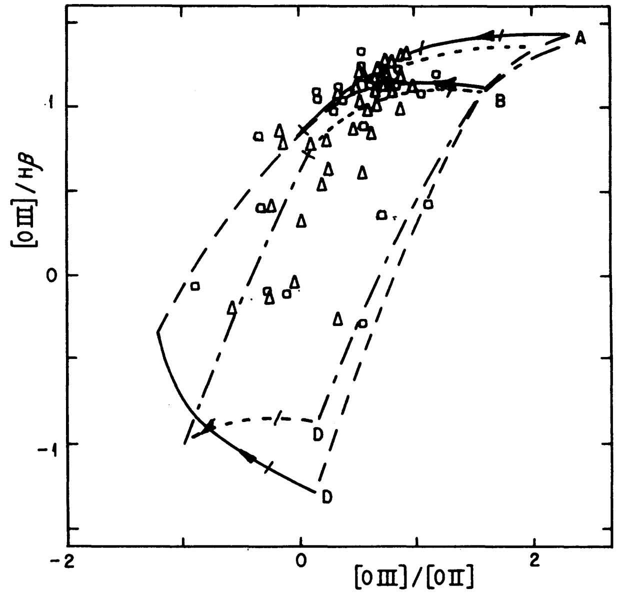

Fig. 1. [O III]5007 + 4959/Hβ versus [O III]5007+ 4959/[O II]3727. Observational data: ◘ radiogalaxies, Δ Seyfert galaxies.

better fitted to observations when including relativistic electrons, as illustrated in Fig. 1. However, since all the models correspond to radiation-bounded clouds, some of the low excitation line intensities are too intense ([NII] 6584 + 6584,[OI] 6300 + 6363, [SII] 6716 + 6731) and the presence of realistic electrons may worsen the theoretical ratios. In these cases a matter-bounded model could be better to fit to observations and even more realistic, i.e., models stopping for values of neutral hydrogen abundance, $n_{H}o/n_{H}$, less than 0.95. Models considering matter-bounded filaments are in preparation. However, since the integrated models are composed by filaments of different densities, the value of $n_{H}o/n_{H}$ at the low ionization edge may be different and models considering the same $n_{H}o/n_{H}$ can only provide an estimate on the low excitation line ratios. A more accurate calculation could be obtained and the real influence of relativistic electrons shown, by comparing theoretical results to observations of individual objects instead of a large sample of them.

REFERENCES

Binette, L., 1985, Astr. Ap. 143, 334.
Cesar, M.L., Aldrovandi, S.M.V., Gruenwald, R.B., 1985, P.A.S.P. 97, 850.
Cohen, R.D., 1983, Ap. J. 273, 489.
Cohen, R.D., Osterbrock, D.E., 1981, Ap. J. 243, 81.
Costero, R., Osterbrock, D.E., 1977, Ap. J. 211, 675.
De Robertis, M.M., Osterbrock, D.E., 1986, Ap. J. 301, 727.
Grandi, S.A., Phillips, M.M., 1979, Ap. J. 232, 659.
Grandi, S.A., Osterbrock, D.E., 1978, Ap. J. 220, 783.
Gruenwald, R.B., Viegas-Aldrovandi, S.M., 1986, Astr. Ap. Suppl. Ser.(in press).
Koski, A.T., 1978, Ap. J. 223, 56.
Osterbrock, D.E., 1981, Ap. J., 249, 462.
Osterbrock, D.E., Koski, A.T., Phillips, M.M., 1976, Ap. J. 206, 898.
Phillips, M.M., Osterbrock, D.E., 1975, P.A.S.P. 87, 949.
Shuder, J.M., 1980, Ap. J., 240, 32.
Shuder, J.M., Osterbrock, D.E., 1981, Ap. J., 250, 55.
Stasinska, G., 1984, Astron. Astrophys. Suppl. Ser. 135, 341.

R.B. Gruenwald: Observatoire de Meudon, DAF, 92195-Meudon, France (present address).
S.M. Viegas-Aldrovandi: Ohio State University, Department of Physics, Columbus OH, 43210, USA (present address).